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## (54) Logging tool and method

(57) A production logging tool for use in deviated wellbores is provided having an elongate tool body (12) and an elongate sensor probe (54) that is capable of lateral movement relative to the tool body. The sensor probe is connected to the tool body by a mechanism serving to deploy the sensor probe such that it is oriented across the wellbore. The tool body has a defined weight and the probe has a weight less than the defined weight, thus causing gravity induced orientation of the sensor probe so as to extend from top to bottom of the fluid passage for sensing all phases of the fluid present therein. The sensor probe (54) is typically of elongate configuration and may support a single elongate sensor (64) or a plurality of independent similar or dissimilar sensors arranged in spaced relation along the length of the probe. Orientation of the sensor probe across the borehole is accomplished mechanically by coil or leaf springs (46, 62) or by a hydraulically or pneumatically powered mechanism or by an electric motor driven mechanism.

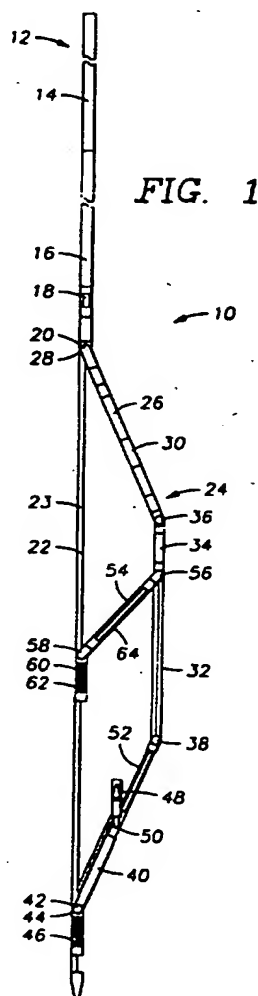


FIG. 1

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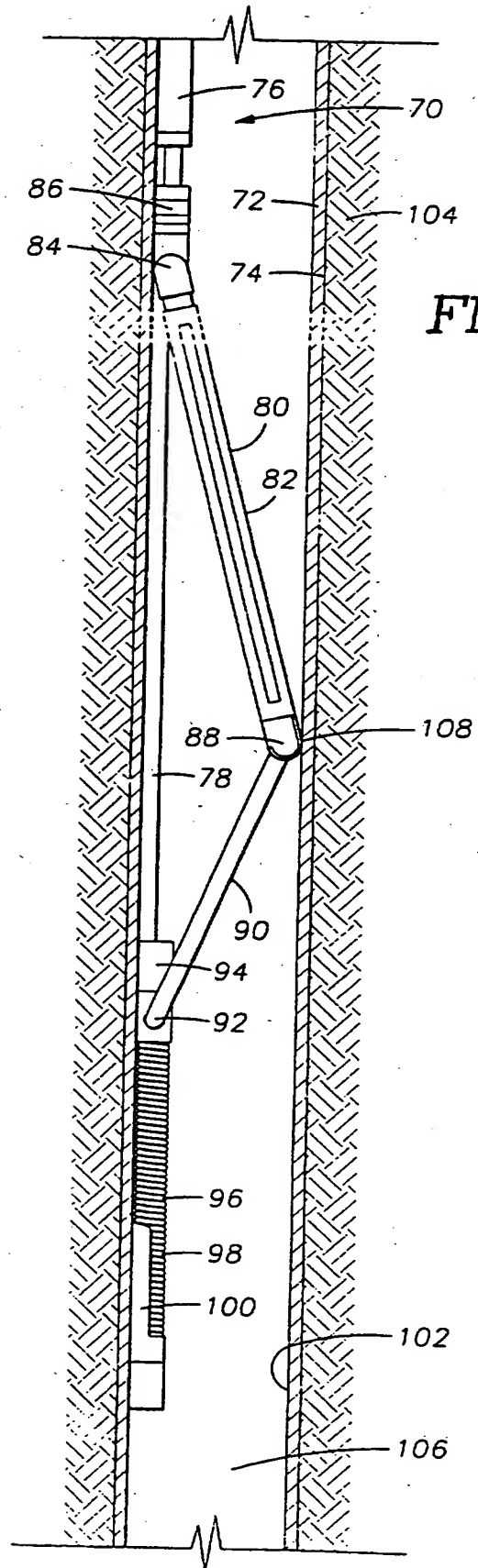
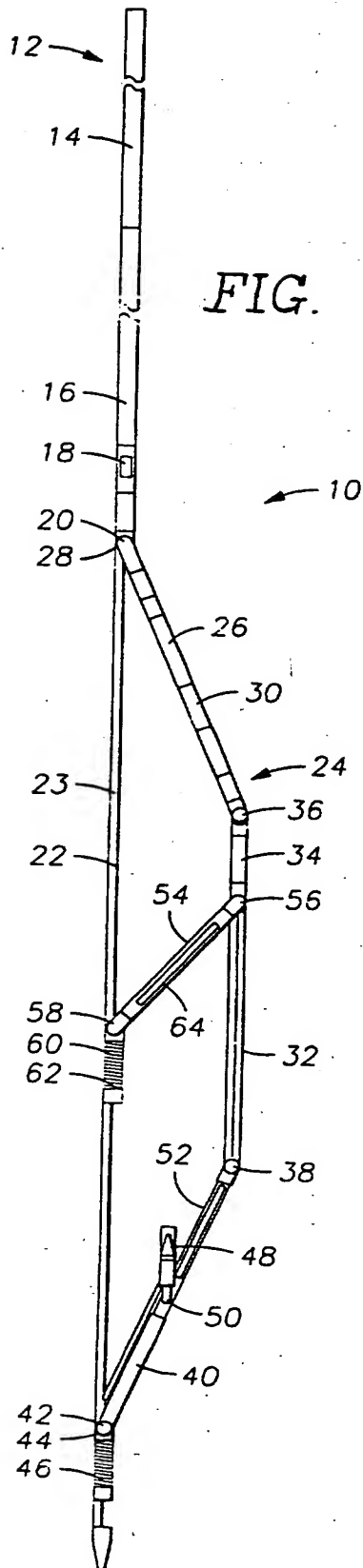
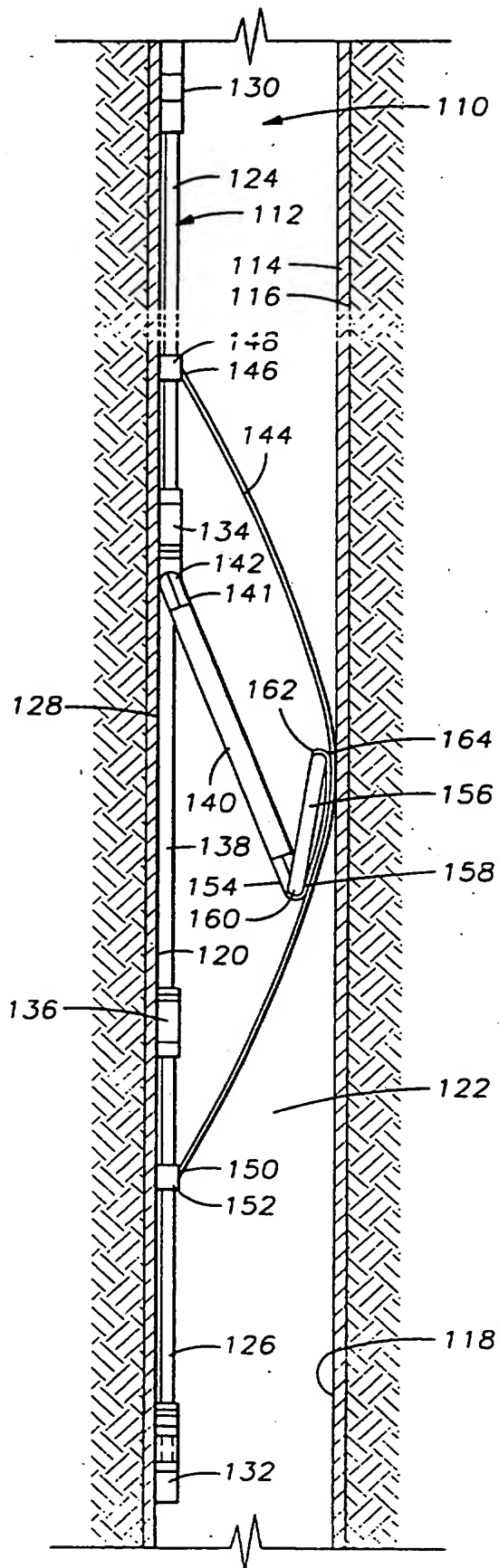


FIG. 3



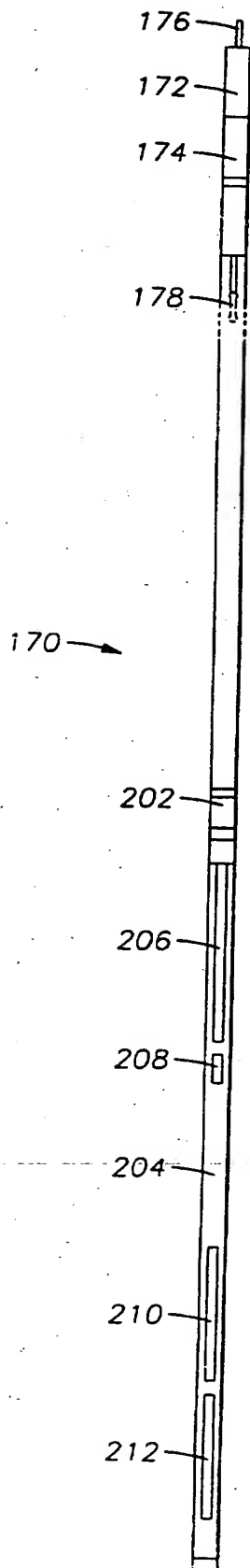


FIG. 4

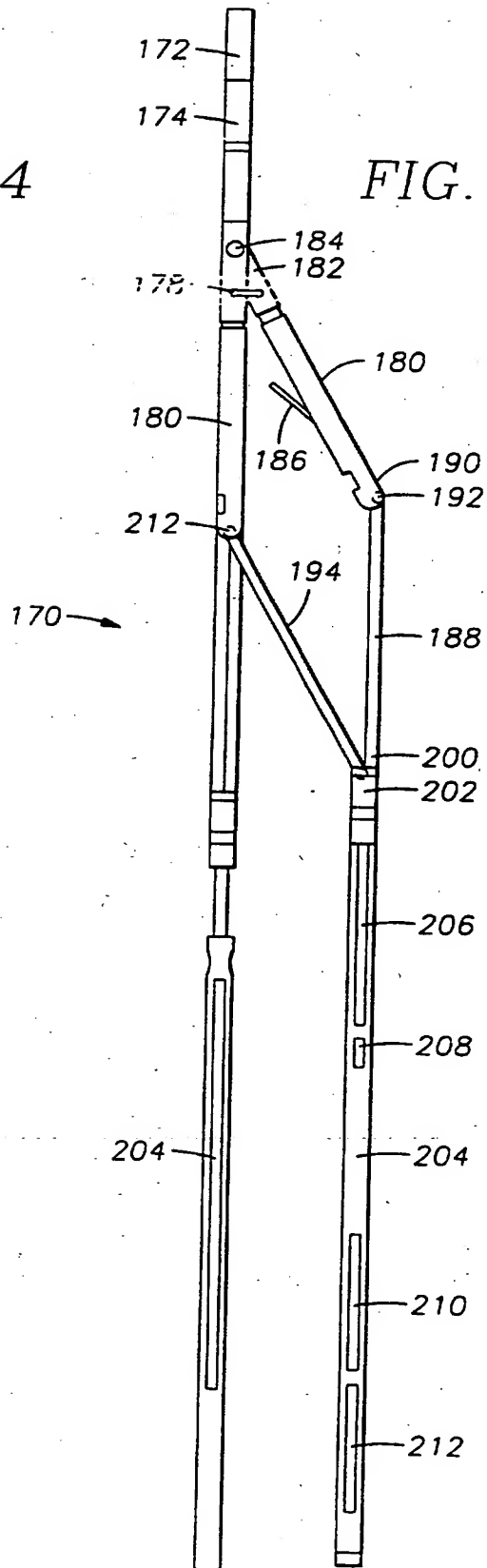


FIG. 5

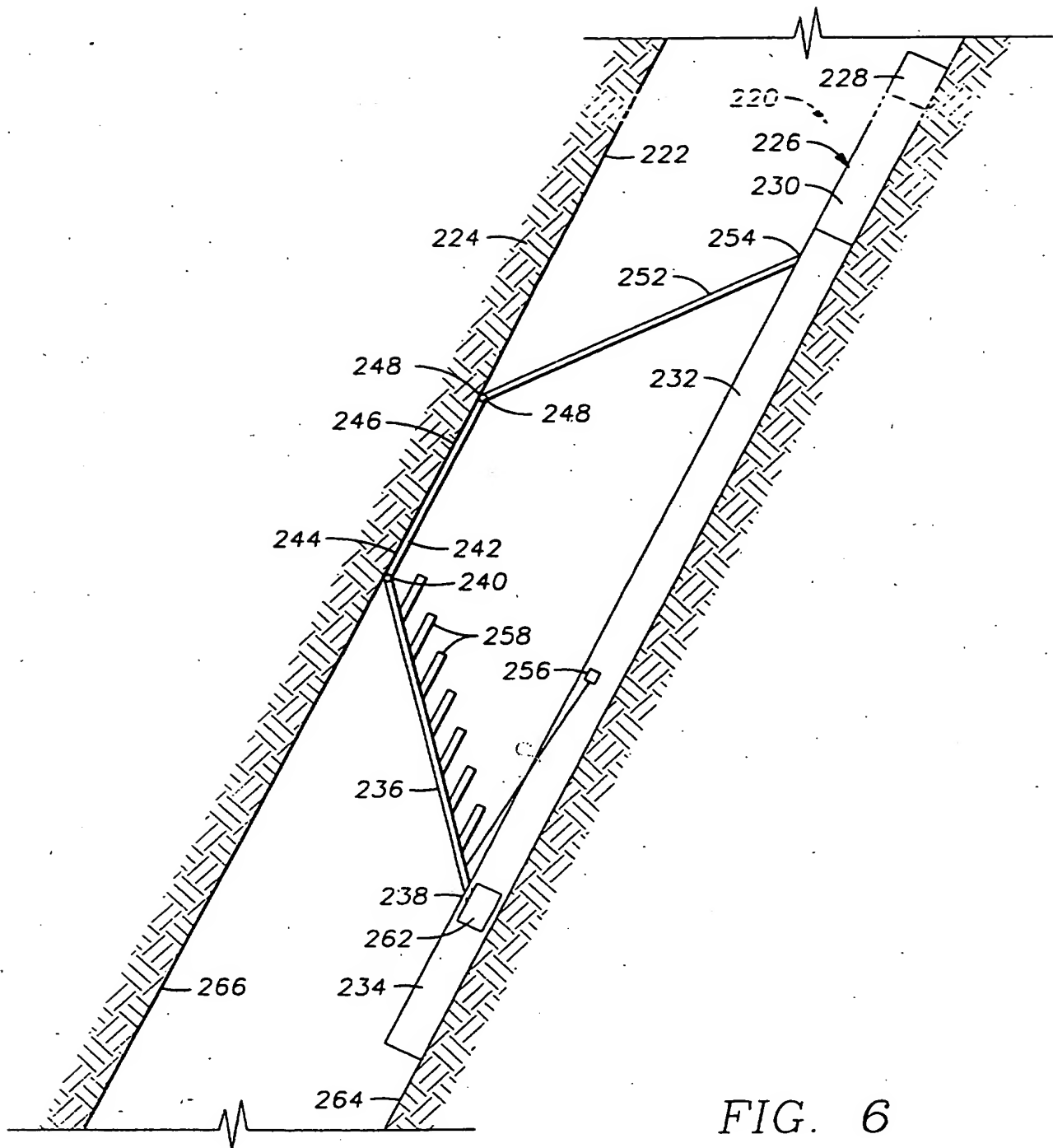


FIG. 6

LOGGING TOOL AND METHOD

This invention relates to logging tools and methods and is applicable to measurement of discrete and average fluid properties of flowing production fluid from wells. This invention also relates to mechanisms for positioning the  
5 sensors of a production fluid logging tool or logging tool of other character to facilitate efficiency of well logging and to permit efficient running of the tool.

As used herein the terms "wellbore", "borehole", and "fluid passage" are intended to encompass any flow passage such as is defined by a drilled bore in an earth formation, a well casing or production conduit that is present within the  
10 drilled bore or any other pipe or tubing that defines a flow passage through which fluid, such as well fluid may flow. The term "fluid" as used herein encompasses liquids such as crude oil and water and gases such as natural gas, as well as mixtures of crude, oil, water and natural gas.

Due to the plurality of fluids in a producing oil well, flow regimes for  
15 the production of petroleum fluids can become extremely complex and segregated. This becomes even more acute in deviated wells for the reason that fluid phases, fluid density and the action of gravity on the well fluid can significantly influence separation of the various phases of the production fluid when the well bore or flow conduit deviates from the vertical. The lighter  
20 density production fluid will rise to the top of the deviated wellbore and pass over the heavier density fluid. Thus, it can be quite difficult to determine the average fluid properties (phase segregation) if conventional, centralized production logging instruments are employed. In wells producing more than one phase, the phases tend to move up the well at different velocities owing to the  
25 difference in densities between the phases and in some cases one or more of the phases will be moving downwardly while other phases are moving upwardly. It has been firmly established that the light-density phases of the production fluid move up the well faster than do the heavy-density phases. It has been established that the lighter phases also occupy a small cross-sectional area when  
30 this phase segregation occurs as a result of wellbore deviation angles.

Through-tubing logging instruments are limited in diameter to the size of

the smallest restriction. These small instruments are traditionally run through the wellbore in such manner that the instrument and the sensors of the instrument are centralized within the wellbore, that is they are held by various means in the center of the pipe. With the instrument thus centralized, the measurement is made inside the tool body by sensors located within the instrument housing. Hence, if a centralized instrument is operated in an inclined borehole with multiple phases present, the instrument might not detect the light phase on the top of the borehole, or the heavy phase on the bottom. The phase detection that is accomplished through the use of conventional instruments can be quite inaccurate when deviated wells are logged. They tend to sense a fluid mixture that has an indicated heavier density and is thus inaccurate owing to the fact that the lighter phase fluid migrates to and remains on the upper wall of the deviated wellbore. This holds true for fluid capacitance type instruments designed to determine the fraction of water in the production fluid mixture that is being produced from a well or present within the wellbore.

Centralized logging techniques utilizing tools with embedded or internal sensors can have a problem with the quality of instrument centralization. If the instrument centralizers used in highly deviated wells do not provide sufficient force to properly overcome the weight of the instrument housing and its contents and to centralize the instrument, the instrument will tend to be decentralized by its own weight and may rest on or near the bottom wall surface of the wellbore. This leads to the sensor of the instrument being positioned in the heavy phase side of the deviated wellbore and the measurements taken to be erroneous with the heavy phase being dominant.

Earlier methods that have been employed as attempted solutions to the problems described above are classified into two general areas: The first attempted solution is the provision of a packer or diverter type production logging instrument. This instrument consists of a packer mechanism or a set of metal petals that is designed to force or divert the total flow of fluid through the body of the instrument to permit the instrument to take accurate readings. These methods overcome the fluid phase segregation problem by forcing all or most

the light and heavy phases into the instrument for measurement. This is usually done with the logging instrument stationary within the wellbore by first lowering the instrument to the desired depth within the wellbore or well casing and then locking it in place and inflating the packer or opening the diverter. When this takes place a large pressure drop is created across the restriction of the smaller instrument flow passage which is incurred by forcing the larger borehole flow through the smaller sensing section of the instrument. This restriction, in combination with the restrictions of the location locking mechanisms of the instrument, can significantly retard the flow of production fluid and thus typically limits the use of these instruments to wells having low total flow rates, usually under 2,000 barrels per day. Additionally, the pressure drop caused by restricted flow with the diverter active may not be the same as when the instrument is removed, thus potentially leading to the gathering of erroneous data about the production capability of the well.

Another solution to the above problems has been a method using a combination of centralizers that, upon command, can open or close. These centralizers are then used in the closed condition in deviated wells to allow the instruments to contact or run on the bottom wall of the deviated wellbore. The measurements that are taken with this type of logging instrument in engagement with the bottom wall of the wellbore will be representative of the fluid phase or phases flowing along the bottom wall or in the lower portion of the flow passage, usually the heavier phase. The instrument is then centralized within the wellbore by opening the centralizers and a conventional reading is acquired. In this conventional position within the wellbore the fluid phase or phases that are present in the central portion of the flow passage will be sensed. Finally, one or a combination of these centralizers is closed or opened in an attempt to kick or shift the instrument to an angled position within the wellbore to sense the fluid phase or phases that are present along the top wall of the deviated borehole. Obviously it is difficult to determine if the instrument has achieved the proper angled position for sensing the fluid regime in the upper portion of the flow passage. Even if instrument positioning as described above is achieved, this



method of production logging does not accomplish simultaneous and continuous sensing of all three areas of interest, so that these well production logs are run sequentially and therefore the data acquired are of different time frames and are sometimes difficult to correlate with each other in order to compute an average  
5 fluid composition.

Various aspects of the invention are exemplified by the attached claims.

According to one aspect of the invention there is provided a logging tool for use in a well fluid passage, the tool comprising an elongate tool body for traversing a well fluid passage, there being by an elongate sensor member  
10 having sensor means along its length to measure a fluid property in the passage, the sensor member being movably supported by the tool body and having positioning means for positioning the sensor member across the well fluid passage so that the sensor means is able to measure substantially all phases of production fluid therein.

15 Various alternative embodiments provide one or more of the following features:

a novel mechanism for accomplishing accurate measurement of average fluid properties of segregated or stratified flowing well fluid phases especially in highly deviated wells;

20 a mechanism for well production logging wherein measurements of average fluid properties are taken simultaneously across-the-wellbore such that all phases of the flowing production fluid are efficiently measured for accurate determination of average fluid properties;

a mechanism for well production logging having the capability of  
25 deploying multiple differing sensors across the borehole, such as for sensing temperature, capacitance and other fluid conditions and to process the sensor signals individually or combine the individual measurements to form the appropriate averages; and

a mechanism for well fluid production logging which, when introduced  
30 within the wellbore, automatically establishes logging tool decentralized positioning of an elongate fluid density sensor member across a deviated

wellbore and generally oriented from top to bottom to provide the capability for simultaneous detection of the heavy phase of the production fluid along the lower wall of a wellbore and the light phase of the fluid that is present along the upper wall of a wellbore.

5           Briefly, one example embodiment comprises an elongate logging tool body having a casing collar locator and having various sensors such as a pressure sensor, gamma ray sensor, density sensor and a telemetry section, the tool body, because of its weight, being positioned by the influence of gravity to engage or ride on the lower wall of a deviated wellbore, there being an actuator  
10   strut mechanism that is movable relative to the tool body and is positioned by a suitable actuator mechanism so that a sensor such as a capacitance probe of the tool or other suitable density measuring device is positioned in inclined relation within the wellbore and extends across the wellbore. A set of springs or other suitable urging means may typically function as the power source of the actuator  
15   strut mechanism and provide sufficient force to hold an engagement section or sensor pad of the tool against the wall of the wellbore opposite the wellbore wall engaged by the body of the tool. Typically the actuator strut mechanism will engage the top wall of the wellbore as the result of gravity influencing tool orientation. Alternatively, the strut actuator may be spring urged to its closed or  
20   retracted position and power operated its open or expanded position so that, in the absence of operating power, it can be automatically retracted to its closed position by the strut spring mechanism. From the standpoint of tool orientation, the combination of gravity acting on the heavier tool body and the force of the springs or other urging means will be sufficient to ensure that the sensor pad  
25   automatically seeks a position so that it engages the upper wall of a deviated wellbore. The capability of the tool to automatically orientate an elongate sensor diametrically across the wellbore and to extend from the upper wall to the lower wall provides for the production of better quality information as to the wellbore fluid quantity and composition. There is no more pressure drop across  
30   the production logging tool than that of a conventional centralized type tool. When such a logging tool is being employed, well production parameters are not

substantially altered. The logging tool mechanism can be run in the continuous mode; that is it can be lowered into and retrieved from the well while taking readings. It is not necessary for such a tool to be stationary while logging measurements are being taken.

5           Such an example of a fluid flow logging tool is naturally in a de-centralized mode in order to take its readings. This eliminates the use of conventional tool centralizers and thereby minimizes the length of the complete tool package that is to be placed in the well. Also, the capability for use of the logging tool in its de-centralized mode minimizes the potential for gathering  
10 erroneous data that might otherwise result if the tool were not centralized. In the case of conventional logging instruments, insufficient centralizing force, thus enabling the influence of gravity to cause the sensor packages to ride nearer to the lower wall of the deviated well bore, typically causes the instrument to sense only the heavier phases of the fluid regime.

15           The advantage of the across-the-borehole type production logging device of this example embodiment is that this instrument, using sensors that are placed in a manner to measure from one side of the borehole to the other, can accomplish a true measurement that is representative of the actual production fluid mixture. This measurement or measurements includes all of the phases  
20 that are present in the fluid mixture. It is desirable, therefore, that a production logging instrument be provided having sensors which measure a combination of the light phases that are present at the top wall of the deviated wellbore and the heavier phase or phases that are located at or near the bottom wall of the wellbore. These measurements are then true representations of the various  
25 phases that might be present in the production fluid; the measurements can be efficiently processed to accurately depict the character of the well fluid flowing or present within the wellbore. Additionally, because the preferred form of the instrument can be run decentralized, the heavier body of the tool will be positioned by the influence of gravity in contact with the lower wall of the  
30 wellbore thus, as a consequence, positioning the lighter weight sensor arm of the tool in contact with the upper wall of the wellbore. As wellbore deviation is

encountered by the tool, the influence of gravity will cause it to be automatically oriented with the tool body in engagement with the lowermost wall of the wellbore or casing and with the sensor arm in engagement with the uppermost wall. This tool therefore obviates the need for rigid centralization of the tool within the wellbore according to conventional practices and thus overcome the disadvantages associated with conventional centralized production logging instruments.

For a better understanding of the invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:-

Fig. 1 is an elevational view of a production logging tool which is constructed in accordance with one embodiment;

Fig. 2 is an elevational view of a production logging tool representing an alternative embodiment and being shown in position within a tubular conduit such as well casing, well tubing, side pocket mandrel or the like;

Fig. 3 is an elevational view illustrating yet a further embodiment and showing a production logging tool in a de-centralized position within a tubular conduit such as a well casing positioned in a borehole drilled in earth formation;

Fig. 4 is a front partial sectional view of a point-to-point profile production fluid logging tool which is shown in its retracted position for a passage through a wellbore or conduit;

Fig. 5 is a side elevational view illustrating the logging tool of Fig. 4 and showing both a collapsed running position of the tool and an expanded or extended sensing position of the tool as would occur when the tool is oriented for sensing within a wellbore; and

Fig. 6 is a sectional view of a deviated borehole within an earth formation and by way of elevational view showing a swing arm type production logging tool situated with its tool body structure de-centralized and in contact with the bottom wall of the wellbore and a sensor arm positioning a plurality of spaces sensors diametrically across the borehole.

Referring now to the drawings and first to Fig. 1, a production logging

tool representing the preferred embodiment is shown generally at 10 and incorporates an elongate generally cylindrical tool body shown generally at 12 having a casing collar locator, a telemetry and gamma ray section 14 and an electronics package section 16. The tool body also includes a pressure sensor 18  
5 and a density source 20.

A section of the elongate tool body 12 is cut-away as shown at 22 to provide a laterally opening receptacle for receiving a sensor positioning mechanism shown generally at 24 when the logging sensor is fully collapsed so as to define a small cross-sectional dimension for traversing the borehole of a  
10 well or conduit to a desired depth and for retrieving the logging tool from the wellbore. The sensor positioning mechanism 24 incorporates any one of a number of suitable actuator means for controllably expanding it to the position shown in Fig. 1 to accomplish de-centralization of the tool body 12 within the passage and to urge the logging sensor mechanism into engagement with the  
15 opposite wall of the passage. At its upper end the sensor positioning mechanism 24 includes an elongate sensor positioning member 26 which is connected by pivot 28 to the tool body at the upper end of the relieved or cut-away tool body section 22. The sensor positioning member 26 is adapted to pivot to a position of substantially parallel relation with the tool body section 23 when disposed at  
20 its fully collapsed position. As shown in Fig. 1, the sensor positioning member 26 is extended from the sensor receptacle 22 to an angled

relation with the tool body section 23. The sensor positioning member may also provide support for other fluid condition detectors such as a temperature probe 30 for detecting the temperature of the flowing fluid medium at a central location within the flow passage or at a multitude of positions. An elongate wall contact member 32 is connected in pivotal  
5 relation with the lower end of the sensor positioning member 26 and is typically intended for orientation in substantially parallel relation with the wall surface of the wellbore or other conduit within which the logging tool is located. This wall contact member 32 may also provide for support of particular well logging instruments such as a density detector 34 which is shown to be connected at the upper end of the member 32. The wall contacting  
10 member 32 is also provided with upper and lower guide rollers 36 and 38 which establish rolling contact with the wall surface of the fluid passage and therefore serve to maintain the wall contact member 32 in parallel juxtaposition with the fluid passage wall surface diametrically opposite the line of contact of the tool body 12 within the wall surface of the fluid passage. A lower elongate probe positioning element 40 is pivotally connected at its  
15 lower end 42 to a spring urged drive member 44 that is disposed in movable relation with the lower end of the tool body section 23. The drive member 44 is urged in an upward direction by a spring 46 in the form of a coil type compression spring. The spring 46 is preloaded when the sensor positioning mechanism 24 is collapsed to its full extent so that when the sensor positioning mechanism 24 is released from its nested relation with the tool  
20 section 23 the spring 46 will urge the lower end of the probe positioning member 40 upwardly thus causing movement of the probe positioning member to an angulated relation with the tool body section 23 as shown in Fig. 1, while at the same time driving the wall contact member 32 outwardly into contact with the wall surface of the fluid passage. As an alternative, to provide for efficient tool retrieval in the absence of operating power, the  
25 spring 46 can be arranged to move the drive member 44 to its closed or retracted position. In this case a drive motor such as a hydraulic or pneumatic actuator can be employed to move the sensor mechanism outwardly with its retraction being accomplished by the force of the spring 44.

The elongate probe positioning member 40 also provides support for a fluid flow sensor 48 referred to herein as a "spinner" which is pivotally connected at 50 to the probe positioning member 40. In the collapsed position of the sensor mechanism 24 it is appropriate for the spinner 48 to be pivoted into nesting relation within a spinner receptacle 52 that is defined by the upper portion of the probe positioning member 40. When the sensor positioning mechanism 24 is extended in the manner shown in Fig. 1, the spinner 48 will be automatically pivoted about its pivot 50 from the nesting receptacle 52 to a position being substantially centrally of the flow passage within which the tool is received and thus oriented substantially parallel with the direction of fluid flow through the flow passage.

Intermediate the extremities of the wall contact member 32 an elongate sensor strut 54 has its upper end pivotally connected at 56 while its lower end 58 is disposed in pivotal connection with a spring urged drive member 60 having a spring 62 which may be in a form of a coil type compression spring as shown. The spring 62, like spring 46 is loaded upon movement of the sensor positioning mechanism to the collapsed position thereof. Upon release of the sensor positioning mechanism from its nested relation with the tool body section 22 of the spring 62 will move the drive member upwardly thereby also moving the pivotal connection 58 upwardly and urging the sensor strut member 54 to the angulated position shown in Fig. 1.

Upon expansion to the position shown in Fig. 1 the sensor positioning mechanism accomplishes de-centralization of the tool body 12 within the flow passage and also positions various sensor components in desired locations within the fluid passage. The temperature probe 30 and the spinner mechanism 48 are located centrally of the flow passage to thus properly locate them for sensing. A capacitance probe 64 is located by the mechanism so that it extends across the flow passage for sensing of all of the various phases of fluid flow within the flow passage. In the alternative, the sensor support 54 may be provided with a plurality of individual production fluid sensors located in spaced relation along the length thereof so that the sensors are each positioned for sensing a particular portion of the cross-section of the fluid passage so that all phases of the fluid may be sensed.

It is desirable that when used in deviated wellbores the logging tool be capable of becoming oriented so that the tool body 12 is in contact with the bottom wall surface portion of the wellbore or conduit while the wall contact member 32 is in contact with the upper wall thereof. This is accomplished by the influence of gravity acting on the different weights of the tool body 12 and the sensor positioning mechanism 24. The tool body 12, including its various components, is of significantly greater weight compared to the weight of the sensor positioning mechanism 24. The influence of gravity on the tool body 12 thereby positions the tool body in contact with the lower wall of the inclined or deviated wellbore or conduit. Since the sensor positioning mechanism is specifically oriented relative to the elongate tool body, the influence of gravity therefore also orients the sensor positioning mechanism so that the wall contact member 32 is disposed in contact with the upper wall surface portion of the wellbore or conduit. The spring enhanced sensor positioning mechanism 24 expands the sensor mechanism sufficiently to move it into contact with the wellbore wall and with sufficient force to accomplish decentralization of the logging tool mechanism within the wellbore. Thus the capacitance probe and other sensors that may be supported by the sensor support 54 are oriented across the wellbore so that all of the phases of the production fluid can be sensed.

Referring now to Fig. 2 an alternative embodiment of the present invention is illustrated generally at 70 which is shown to be positioned within a well casing 72 extending through a wellbore 74 in an earth formation. The production logging tool 70 incorporates an elongate tool body 76 having a cut-away portion 78 defining a receptacle for a sensor support mechanism shown generally at 81, having a flow housing 80 incorporating an elongate capacitance probe 82. The elongate housing 80 is pivotally connected at its upper end 84 with a connection mechanism 86 which is disposed in fixed relation with the upper portion of the tool body 76. The elongate housing 80 defines a portion of a capacitance probe linkage mechanism and is pivotally connected at its lower end 88 to a sensor support strut 90 which in turn has its lower end 92 connected to a sensor drive element 94 that is disposed in movable relation with the lower portion of the tool body. The sensor drive



element 94 is acted upon by a spring 96 which may take the form of a compression type coil as shown. The lower end of the spring 96 is interconnected with a spring retainer 98 which is received within the lower end portion 100 of the tool housing structure. The spring 96 supplies sufficient mechanical force against the capacitance probe support 80 to urge one end of the support into engagement with the internal wall surface 102 of the well casing 72 and to force the elongate tool body 76 into engagement with the opposite wall surface 104 as shown in Fig. 2. In this manner, the spring 96 accomplishes decentralization of the tool body 76 within the well bore or conduit defining the flow passage and positions the lower end 88 of the capacitance probe 80 so that the lower end of the capacitance probe 82 is located in juxtaposition with the casing wall surface 102 and the upper end of the capacitance probe is located in juxtaposition with the diametrically opposite wall of the wellbore. The capacitance probe 82 is therefore located so as to extend across the flow passage defined by the wellbore so that in this inclined position it can sense all phases of the production fluid which are present within the flow passage 106. The sensor mechanism can remain in the position shown in Fig. 2 during running of the tool into the casing 72 to thus permit the capacitance probe to accomplish fluid sensing on a continuous basis as the tool is moved downwardly or upwardly within the flow passage. Interconnection of the sensor housing 80 and the sensor positioning strut 90, essentially at the pivotal lower end connection 88, may be established by a wear plate 108 that resists wear and damage to the sensor mechanism of the tool as it is moved along the inside of the well casing. As an alternative, as mentioned above the spring assembly may be employed to retract or close the sensor mechanism 81 in the absence of power. A powered actuator, operating against the closing force of spring 96, is used to move the sensor mechanism to its open or Fig. 2 position. When opening power is discontinued, the closing spring 96 will retract the capacitance probe within its receptacle 78 for efficiency of running the tool through the wellbore.

Referring now to Fig. 3, a further alternative embodiment of this invention is shown generally at 110 having an elongate tool body structure which is shown to be positioned

within a well casing 114 extending through a wellbore that is drilled within an earth formation. Through shown in Fig. 3 as being vertical, the well casing 114 and the wellbore 116 may be inclined from the vertical or even horizontal, such as in the case of deviated or horizontally drilled wells so that internal casing surface 118 will represent the top wall of the casing while the diametrically opposite wall casing surface 120 will be located as the bottom wall. The well casing 114 defines a fluid passage 122 within which the production fluid is either static or moving.

The elongate tool body 112 defines an upper connector section 124, a lower connector section 126 and an intermediate sensor body section 128 the upper and lower connector sections 124 and 126 are provided respectively with connector mechanisms 130 and 132 for connection thereof to other tools and instruments that may be extended into the wellbore in conjunction with the logging process. The connector section 124 is provided with a lower connector 134 having connection with the upper end of the intermediate body section 128. Likewise, the upper end of the lower connector section 126 is provided with an upper connector 136 for connection with the lower end of the intermediate body section 128. The body section 128 is cut-away as shown at 138 to provide an elongate receptacle for receiving an elongate sensor housing 140 that is pivotally connected at its upper end 142 to the connector mechanism 134 and is pivotal from the extended, angulated position shown in Fig. 3 to a position where it is received in nesting relation within the elongate receptacle 138 of the tool body.

When the logging tool 110 is located within the well casing and sensing is desired it is appropriate for the elongate sensor housing 140 to be pivotally moved from the receptacle 138 to a position where the sensor housing extends transversely across the flow passage 122. This feature is accomplished by the provision of a bow spring 144 having its upper end 146 fixed to a movable guide element or slide connector 148 which circumscribes the connector section 124 and is slidable along the length of the connector section to permit expansion and collapsing of the spring 144. Likewise the lower end 150 of the bow spring is disposed in connection with a slide connector 152 which is movably received about the

lower connector section 126. The lower end 154 of the elongate sensor housing 140 is disposed in actuating contact with the bow spring as shown to thereby permit extension or collapsing of the housing 140 as the bow spring 144 extends or collapses. If desired, the lower end of the housing 140 may be defined by a guide roller which establishes a movable, guided relation with the bow spring in addition to establishing and actuating engagement with the bow spring. An elongate detector element 156 has its lower end 158 connected to the sensor housing 140 by means of a pivot arrangement 160. Additionally, the upper end 162 of the sensor is provided with a guide member 164 which establishes engagement with the bow spring 144 to ensure positioning of the upper end 162 of the detector in juxtaposition with the wall surface 18 of the well casing. The bow spring 144 is capable of being collapsed by moving its central portion toward the sensor receptacle 138. When this movement occurs, the movable slide connector elements 148 and 152 will move along the length of the respective connector sections 124 and 126 sufficiently to permit the amount of spring collapse that is desired. The bow spring will automatically extend to the position shown in Fig. 3 when it is not otherwise constrained and will have sufficient extension force to induce decentralization of the tool body to maintain the tool body and sensor mechanism in the position shown in Fig. 3. In this position, the sensor housing 140 will be inclined so that it is located across the flow passage 122 so that its sensor assembly defines a sensor array across the borehole. The sensor array may be an across-the-borehole capacitance sensor of the nature shown at 64 in Fig. 1 or a plurality of individual sensors, which may be a plurality of like sensors or a sensor array having differing sensors or groups of differing sensors. The sensor or sensor array, regardless of its character, will be adequately positioned across the borehole and typically oriented from the bottom to top in relation to the inclined or deviated fluid passage of the wellbore for detection of all phases of fluid within the fluid passage 122. Due to the heavier weight of the tool body relative to the sensor mechanism, the tool body will automatically seek engagement with the bottom wall of the well bore under the influence of gravity and will thus orient the sensor mechanism so that it engages the top wall of the well bore.

A further alternative embodiment of this invention is shown generally at 170 in Figs. 4 and 5 with Fig. 4 showing the logging tool in its fully collapsed condition such as for traversing the well casing or wellbore. Fig. 5 illustrates the tool both in its collapsed or running position for movement through the wellbore and in its extended or expanded condition for decentralizing the tool within the wellbore or well casing and for location of the sensors on the high side of an inclined wellbore or well casing such as for positioning of a spinner, gamma ray source, density or gamma ray detector and a capacitance probe in the region of the high side of the flow passage if desired. In vertically oriented wellbores or well casings the logging tool provides for location of the spinner, gamma ray source detector and capacitance probe adjacent the wall surface of the wellbore or well casing. At its upper end the logging tool defines a tool support body 172 having an internal, linearly movable actuator 174 having its upper end 176 being exposed to receive an upward or downward actuating force. The lower end of the actuator element 174 is provided with an actuator linkage 178 having operative driving relation with an elongate sensor housing 180 having its upper end 182 connected by pivot 184 to the housing structure. The sensor housing may be provided with a temperature sensor 186 which in the extended condition of the mechanism, is located substantially centrally of the flow passage of the well casing or other flow conduit. The sensor housing 180 is also shown in Fig. 5 in the fully collapsed position thereof. An elongate actuator linkage element 188 is movably assembled to the lower end 190 of the actuator housing by a pivot connection 192. Another actuator link 194 is movably connected to the tool housing by a pivot connection 196 at its upper end. The lower end of the actuator link 194 is secured by pivot connection 198 to the linkage element 188 and is disposed in substantially parallel relation with the elongate sensor housing 180. The linkage element 188 is fixed at its lower end 200 to a connector mechanism 202 of a sensor housing 204. Thus, upon actuation of the mechanism 74-78, the sensor housing 180 is translated outwardly or laterally to the offset position shown in Fig. 5, causing the linkage struts 188 and 194 to maintain the sensor housing 204 in substantially parallel relation with the upper, tool support end 172 of the tool body. When the sensor housing 204 is shifted

laterally in this manner it can be positioned in line contact with or in close proximity to the inner wall surface of the well casing or wellbore thereby provided efficiency of signal transmission to and from the formation being logged. The sensor housing 204 is provided with a spinner 206, a gamma ray or other source 208 at its upper end and is provided at its lower end with a gamma ray detector 210 and a capacitance probe 212. Operation of the logging tools of the various embodiments disclosed herein within an inclined or deviated wellbore is depicted in Fig. 6. As shown, the well logging tool is illustrated generally at 220 and is shown to be located within a deviated well bore 222 which is drilled through an earth formation 224. The logging tool 220 with a housing structure shown generally at 226 having an upper connection section 228, an electronic section 230, a transmitter section 232 and a motor and caliper section 234. An elongate sensor element or housing 236 is connected by pivot 238 to the motor and caliper section and is connected at its remote end 240 to a wall engaging pad member 242 having therein a gamma ray detector 244 and a gamma ray receiver 246. The connection 240 is preferably a pivotal connection, thereby permitting the wall contact member 242 to establish sufficient surface-to-surface engagement with the wall surface of the well bore. The opposite end 248 of the wall engaging pad 242 is connected by a pivot 250 to a pad positioning strut 252 having its opposite end 254 establishing pivotal connection with the tool body structure. A source 256 is provided for sensing the density of the fluid.

The elongate housing 236 is provided along its length with a plurality of sensors or a sensor array to provide signal output relating tool desired parameters of the well being logged. The sensor array may comprise one or more flow rate meters, temperature sensors, capacitance sensors, gamma ray detectors, acoustic impedance meters such as shown collectively at 258 for the purpose of detecting the condition of the various phases of fluid within the flow passage defined by the wellbore. Centrally of the wellbore, the housing structure 236 provides a temperature probe 260 for accomplishing temperature measurement of the fluid centrally of the wellbore. The motor and caliper section 234 accomplishes linear movement of a drive element 262 which the housing structure 236 is pivotally

connected and thereby is operative to cause expansion or contraction of the sensor linkage for the purpose of positioning the pad member 242 into efficient contact with the wellbore or retracting the pad member and the linkages defined by the housing 236 and link 252 into nested relation within a receptacle located  
5 in the elongate tool body. Thus, the linkages efficiently movable to the position shown in Fig. 6 with sufficient force to decentralize the elongate tool body with respect to the wellbore. Since the tool body 226 is significantly heavier as compared to the weight of the pad 242 and its linkage system 236 and 252, when disposed within a deviated wellbore the tool body will become oriented by  
10 gravity into contact with the lower wall surface 264 of the wellbore while the sensor pad 242 will be oriented for engagement with the diametrically opposite upper wall surface 266 of the wellbore.

In view of the foregoing, it is evident that at least some embodiments of the present invention can be so designed as to attain most if not all of the  
15 objects and features hereinabove set forth, together with other objects and features which are inherent in the various apparatus disclosed herein.

As will be readily apparent to those skilled in the art, the present invention may be produced in other specific forms without departing from its spirit or essential characteristics. The present embodiments are therefore to be  
20 considered as illustrative and not restrictive.

CLAIMS

1. A logging tool for use in a well fluid passage, the tool comprising an elongate tool body for traversing a well fluid passage, there being an elongate sensor member having sensor means along its length to measure a fluid property  
5 in the passage, the sensor member being movably supported by the tool body and having positioning means for positioning the sensor member across the well fluid passage so that the sensor means is able to measure substantially all phases of production fluid therein.

2. A production logging tool, for use in a well fluid passage,  
10 comprising an elongate tool body, for versing a well fluid passage, characterised by an elongate sensor probe or member movably supported by said tool body; and means for positioning said elongate sensor probe member across said well fluid passage for detection of all phases of production fluid present therein.

3. A logging tool according to claim 1 or 2, for use in a well fluid  
15 passage which deviates from the vertical, said logging tool comprising means for orientating said elongate tool body to engage a bottom wall of said well fluid passage and for orientating said elongate member to engage said top wall of said well fluid passage.

4. A logging tool according to claim 3, wherein the orientating  
20 means are arranged to locate said elongate member substantially within a vertical plane intersecting said top and bottom walls of a well fluid passage.

5. A logging tool according to claim 2, 3 or 4, wherein said means for orientating said elongate tool body comprises a first weight defined by said elongate tool body, and a second weight defined by said elongate member and  
25 being less than said first weight, and said first and second weights being orientatable by gravity such that said elongate member can be located uppermost and be orientated across a well fluid passage.

6. A logging tool according to any one of the preceding claims, and comprising a sensor pad disposed for engagement with a wall of said fluid  
30 passage, means connecting said sensor pad in movable engagement with said elongate tool body, the sensor member being interconnected with said elongate

tool body and with said sensor pad and, upon movement of said sensor pad into engagement with said wall of said fluid passage, being orientated in diametrical relation across said fluid passage for said sensing of all phases of production fluid within said fluid passage, and means for selectively urging said sensor pad  
5 into engagement with said wall of said fluid passage.

7. A logging tool according to claim 6, wherein said means connecting said sensor pad in movable engagement with said elongate tool body comprises a mechanical linkage interconnecting said elongate tool body and said sensor pad and spring means acting between said elongate tool body and said  
10 mechanical linkage and urging said linkage in a predetermined direction.

8. A logging tool according to claim 6, wherein said means connecting said sensor pad in movable engagement with said elongate tool body comprises spring means acting between said elongate tool body and said sensor pad and urging said sensor pad in a predetermined direction.

15 9. A logging tool according to claim 8, wherein said spring means comprises a bow spring having upper and lower ends thereof interconnected with said elongate tool body and having a central portion thereof disposed in urging relation with said sensor pad.

10. A logging tool according to any one of claims 6 to 9, wherein  
20 said means for selectively moving said sensor pad into engagement with said wall of said fluid passage comprises a power energized mechanism interconnecting said elongate tool body and said sensor pad and being operative upon energization for moving said sensor pad into engagement with the wall of said fluid passage with sufficient force to decentralize said elongate tool body  
25 within said fluid passage and maintain said elongate tool body in engagement with said wall of said fluid passage.

11. A logging tool according to any one of the preceding claims wherein said sensor member is a single elongate sensor capable of detecting a plurality of fluid phases within the diametrical cross-section of said fluid  
30 passage.

12. A logging tool according to any one of claims 1 to 10, wherein



said sensor member is an elongate sensor support having a plurality of sensors at spaced apart locations along the length thereof and being capable of detecting a plurality of fluid phases within said fluid passage.

13. A logging instrument, for use within wellbores, comprising:  
5        an instrument support adapted for connection with an instrument running and actuating tool;

      first elongate sensor housing in pivotal connection with said instrument support;

      a second elongate sensor housing in pivotal connection with said first  
10       elongate sensor housing and being movable to selected laterally translated position within a wellbore;

      an actuator link pivotally connected to said instrument support and pivotally connected to said second elongate sensor housing and cooperating with said elongate sensor housing to maintain said second elongate sensor housing in  
15       substantially parallel relation with said instrument support at all positions of lateral translation thereof; and

      sensor means supported by said second elongate sensor housing for conducting logging operations with said wellbores.

14. A logging instrument according to claim 13, comprising sensor  
20       means within said first sensor housing for positioning across said wellbore when said second elongate sensor housing is in a laterally translated position within said wellbore.

15. A logging tool according to any one of the preceding claims wherein the sensor member or housing is arranged so as to adopt a position  
25       adjacent and partially within the tool body to facilitate traversal of a wellbore by the tool prior to the deployment of the member or housing.

16. A method of production logging within deviated or horizontal wellbores defining upper and lower walls, comprising:

      positioning within said wellbore a production logging instrument having  
30       an elongate tool body and having an elongate sensor probe pivoted at one end thereof to said elongate tool body, said elongate sensor probe having at least one

sensor located along the length thereof;

pivoting said elongate sensor probe from said elongate tool body to a position wherein said elongate sensor is oriented across said wellbore with a portion thereof in contact with the wall of said wellbore opposite said elongate tool body; and

sensing, by means of said probe, the various phases of well fluid that are present across the wellbore.

17. A method according to claim 16, comprising causing decentralization of said elongate tool body within said wellbore.

10 18. A method of according to claim 16 or 17, wherein said elongate sensor probe provides support for a plurality of sensors disposed in spaced relation along the length thereof, said method comprising sensing a plurality of differing well fluid parameters.

19. A method according to claim 18, said method comprising sensing a plurality of differing well fluid parameters.

20. A method according to claim 19, wherein said sensor probe comprises a plurality of individual sensors located in spaced relation along the length thereof for sensing well fluid temperature, phase segregation, acoustic impedance and fluid capacitance.

20 21. A method according to any one of claims 16 to 20 and comprising conducting fluid sensing activities while said production logging instrument is being moved within said wellbore.

22. A method according to any one of claims 16 to 20 and comprising positioning said logging instrument as a selected depth within said wellbore, conducting fluid sensing activities while said logging instrument is stationary, and repeating said positioning and fluid sensing activities sequentially until desired sensing has been accomplished.

23. A logging tool substantially as hereinbefore described with reference to Fig. 1, or Fig. 2, or Fig. 3, or Figs. 4 and 5, or Fig. 6, of the accompanying drawings.

24. A method of production logging substantially as hereinbefore

described with reference to Fig. 1, or Fig. 2, or Fig. 3, or Figs. 4 and 5, or Fig. 6, of the accompanying drawings.





Application No: GB 9520796.5  
Claims searched: 1 to 12 and 16 to 24

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Date of search: 14 December 1995

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK CI (Ed.N): E1F (FHU)

Int CI (Ed.6): E21B 17/10, 47/01

Other: Online database: wpi

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2178088 A (GEARHART TESSEL) whole document	
A	US 4914826 (NOLD, III) whole document	

X Document indicating lack of novelty or inventive step  
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